

## NEW RECORDS WITH ECOLOGICAL NOTES FOR RARE AQUATIC VASCULAR PLANTS IN INDIANA. PART 1

ROBIN W. SCRIBAILO<sup>1</sup> AND MITCHELL S. ALIX<sup>2</sup>

Department of Biology, Purdue University North Central,  
Westville, IN 46391-9542

<sup>1</sup>e-mail: rscrib@purdue.edu

<sup>2</sup>e-mail: alix@purdue.edu

**ABSTRACT.** Floristic inventories of lakes in northern Indiana have resulted in the documentation of 22 new localities for eight Indiana state-listed aquatic plant species. Six of these eight species are listed as endangered (*Bidens beckii*, *Myriophyllum pinnatum*, *Najas gracillima*, *Potamogeton epihydrus*, *P. pulcher*, and *P. vaseyi*) and two are listed as extirpated (*Lemna valdiviana* and *P. bicupulatus*). Many of these species are listed in other states within the Great Lakes region. Each species is discussed in terms of notable characters useful in identification, historical and current information on distribution, and notes on the ecology and species associates for each new site record. Possible explanations for the rarity of these aquatic plant species are discussed in terms of habitat loss, undercollecting, and the “Prairie Peninsula” concept. A brief discussion of problems associated with aquatic plant conservation in the state of Indiana is provided.

**Key Words:** Indiana flora, aquatic plants, rare and endangered macrophytes, naiads, duckweeds, pondweeds, Prairie Peninsula

Aquatic plants are an integral component of aquatic ecosystems, contributing in many diverse ways to the ecological integrity of lakes (Carpenter and Lodge 1986; Jeppesen et al. 1998). The aquatic plant flora of lakes has been extensively documented for many states within the Great Lakes region, such as Michigan, Illinois, Ohio, and Wisconsin. Despite considerable floristic work in Indiana, the aquatic plant flora of its lakes has remained poorly cataloged.

The first comprehensive flora of Indiana was that by Coulter (1900), which was followed by Deam’s (1940) classic volume *Flora of Indiana*. No updated flora has been published since Deam’s work. Although both floras list many aquatic plant species and provide site localities by county, the collecting of true aquatic plants was sporadic in its coverage of the state and biased towards emergent species. *Plants of the Chicago Region* (Swink and Wilhelm 1994), which includes six counties in northwest Indiana, is one of the few more recent floristic treatments available



for the state. It is noteworthy that the treatment of floating and submersed aquatic plant species in this volume is largely based on limited older herbarium collection data from the region and only minimal field surveys (F. Swink, pers. comm.).

Since Deam's floristic surveys, Indiana lakes, streams, and wetlands have suffered extensive habitat loss and degradation due to development. It is estimated that Indiana has lost 89% of its pre-settlement wetlands (National Research Council 1992). The Lake District, which includes the three northernmost tiers of counties in the state, contains over 500 small and shallow lakes averaging only 34.4 ha in size and 11.9 m in maximum depth (Frey 1966).

The small total volume and extensive shallow littoral zones of these lakes make them highly susceptible to eutrophication. The major form of impact is nutrient and sediment loading from surrounding farmland within the watersheds. Many lakes are characterized by extensive growths of spatterdock or Eurasian water-milfoil that often choke the vast majority of the lake's surface area.

As part of an effort to better understand Indiana's lake plant flora and provide more current records on the status of species, we began comprehensively surveying Indiana lakes in 1997. During the summer and early fall months of 1997 through 2001, many new localities for over 30 state-listed aquatic vascular plant species were recorded for Indiana during floristic quality assessment surveys of over 100 lakes and ponds. Because we believe that much of the aquatic plant flora of Indiana lakes has been overlooked and undercollected, specific efforts were made: 1) to locate new populations of state-listed species; 2) to determine the rarity of these species on a state-wide basis; 3) to begin the development of conservation strategies for those species of particular concern.

This paper is the first in a series of papers on rare aquatic plant species of Indiana. Information is provided here on eight state-listed aquatic plant species, which are presented in alphabetical order. The following information is provided for each species: a description of distinctive morphological features, including notes on closely related taxa if the discussion has bearing on identification issues; a summary of historical records and current distribution within Indiana; a brief narrative describing each new population, including information on site locality, habitat type, and associated species; and a listing of voucher specimens. Recom-



mendations for conservation strategies will be briefly discussed as well, although a more detailed analysis will be presented in a separate publication.

#### MATERIALS AND METHODS

**Systematics.** Taxonomy and nomenclature follow that of the *Flora of North America* (1993+) for the following families: Lemnaceae (Landolt 2000), Najadaceae (Haynes 2000), and Potamogetonaceae (Haynes and Hellquist 2000). For species in families not yet treated in the *Flora of North America*, nomenclature follows Gleason and Cronquist (1991). When appropriate, we have included synonymy where nomenclatural differences exist for the species discussed.

**State status definitions.** The designated Indiana state status for a given plant species follows the definitions from the Indiana Department of Natural Resources, Division of Nature Preserves (R. Hellmich, pers. comm.):

1. Endangered = plants that currently occur at five or fewer sites in Indiana.
2. Threatened = plants that currently occur at six to 10 sites in Indiana.
3. Rare = plants that currently occur at 11–20 sites in Indiana.
4. Extirpated = plants that are considered native to Indiana, but currently do not occur within the state.

The state status of each species is provided in Table 1 for the Great Lakes states, however, it should be noted that the criteria used to define the status of a species vary considerably from state to state and do not necessarily conform to those that have been outlined here for Indiana.

**Element of occurrence records.** Element of occurrence records, referred to hereafter as EORs, from the Indiana Department of Natural Resources, Division of Nature Preserves are cited for each species. These records provide both current and historical information on locations for each of the species discussed here. It should be noted that an EOR does not necessarily indicate that a species has been collected, but more often that it has been observed at a particular location. Where available records are



Table 1. Summary of eight imperiled aquatic vascular plant species in the Great Lakes region (modified from a compilation of state checklists: Illinois Endangered Species Protection Board 1999; Indiana Natural Heritage Database 1996; Michigan Natural Features Inventory 1999; Minnesota Natural Heritage Database 2000; Ohio Division of Natural Areas and Preserves 1998; Pennsylvania Natural Diversity Inventory 2002; Wisconsin Natural Heritage Program 1998; Young 2001). State status abbreviations used here: E = Endangered; S = Special Concern; T = Threatened; U = Undetermined; W = Watchlist; X = Extirpated.

| Taxon                          | State and Status |    |    |    |    |    |    |    | No.<br>of<br>list-<br>ings |
|--------------------------------|------------------|----|----|----|----|----|----|----|----------------------------|
|                                | IL               | IN | MI | MN | NY | OH | PA | WI |                            |
| <i>Bidens beckii</i>           | E                | E  |    |    | W  | X  | E  |    | 5                          |
| <i>Lemna valdiviana</i>        |                  | X  | X  |    | E  | X  | X  |    | 5                          |
| <i>Myriophyllum pinnatum</i>   |                  | E  |    |    | E  |    |    |    | 2                          |
| <i>Najas gracillima</i>        |                  | E  |    | S  |    | E  | T  |    | 4                          |
| <i>Potamogeton bicupulatus</i> |                  | X  | T  | E  |    |    | U  |    | 4                          |
| <i>Potamogeton epihydrus</i>   |                  | E  |    |    |    |    |    |    | 1                          |
| <i>Potamogeton pulcher</i>     | E                | E  | T  |    | T  | T  | E  | E  | 7                          |
| <i>Potamogeton vaseyi</i>      |                  | E  | T  | S  |    | X  | E  | S  | 6                          |

numerous, we have summarized the distribution of these records and given the most recent EOR.

**Collection of aquatic plants.** Since an implicit purpose of this study is to identify populations of state-listed species before they are lost, our methods, out of necessity, have been qualitative to allow us to survey individual lakes more efficiently and thus include more lakes in our study. All initial lake inventories were conducted by both authors, during which we attempted to survey the entire littoral zone of the lakes investigated. Proportionately more time was spent at locations that likely harbored the greatest diversity, such as undisturbed shoreline areas or shallow sheltered bays. Relative abundance for each population was determined by visual inspection. In most cases, after a population was discovered the site was revisited annually to check on its status.

Submersed, emergent, and free-floating macrophytes were collected while wading in the shallow water along the lake margin. In areas having moderate depths, the sampling of submersed plant species was carried out by dredging the lake bottom with an extendable rake from the side of a Jon boat. Submersed aquatic plants in areas having a depth > 4.0 m were collected using



SCUBA. By employing multiple methods, a larger proportion of the lake could be comprehensively inventoried and the likelihood of sampling rare species was greatly increased. Voucher specimens have been deposited in either the Aquatic Plant Herbarium of Purdue University North Central (indicated here as PUNC) or the Friesner Herbarium at Butler University (BUT).

Percent seed set was determined by visual inspection of infructescences and estimations of the number of mature seeds per spike versus the total number of flowers. This nondestructive method was used because of concerns over species rarity.

#### RESULTS AND DISCUSSION

***Bidens beckii* Torr.** *Bidens beckii*, often cited as *Megalodonta beckii* (Torr.) Greene, is commonly referred to as the water marigold. It is the only submersed aquatic member of the genus *Bidens* L., which comprises some 200 species (Gleason and Cronquist 1991), many of which are emergent wetland species. The water marigold exhibits a heteroblastic sequence of development, culminating in the production of emergent leaves associated with flowering. The emergent leaves are simple, opposite, and sessile, having either toothed or serrated margins. In deeper water, plants often lack the bract-like emergent foliage and fail to flower (pers. obs.). The submersed leaves of *B. beckii* are characterized by having finely dissected leaves crowded at nodes with varying degrees of similarity to the leaves of several other aquatic species in the genera *Cabomba* Aubl., *Myriophyllum* L., *Ranunculus* L., and *Utricularia* L., with which it is often confused (Peattie 1930; Voss 1996). Voss (1996) described the leaves as being opposite, but branching, giving the foliage a whorled appearance. Flowers are borne in emergent heads, having the typical yellow ray florets that are characteristic of the genus. Some authors believe that differences in the morphology of the florets, awn lengths of the achenes, and chromosome number warrant the segregation of the water marigold from *Bidens* into the genus *Megalodonta* Greene (see Roberts 1985).

Although *Bidens beckii* is found throughout the Midwest, it is state-listed in over 50% of the Great Lakes states (Table 1). Historical records are somewhat vague as to the distribution and abundance of this species in Indiana. Pepoon (1927) and Peattie (1930) suggested that this species was quite rare in northwestern



Indiana during the early 1900s, having been collected or observed from only a few small intradunal ponds in Lake County. Deam (1940) reported this species from seven counties in northern Indiana and suggested that it was once probably found throughout most of northern Indiana, but had likely been destroyed by lake-front settlement. Swink and Wilhelm (1994) reported *B. beckii* from LaPorte County, based on a single collection from Stone Lake in August of 1983 (*Rowlatt 1297*, MOR). This is the last known collection for the state prior to the current study. Indiana EORs simply refer to the original site records from Deam (1940).

During the fall of 1997, we found *Bidens beckii* along the northwestern littoral zone of Stone Lake, LaPorte County, in water 1.0 m deep with the entire population consisting of less than 60 plants. Plants did not have the emergent foliage associated with flowering. Plants growing in association with *B. beckii* were *Myriophyllum sibiricum* Kom., *Potamogeton robbinsii* Oakes, *P. zosterformis* Fernald, *Ranunculus aquatilis* L. var. *diffusus* With., and *Vallisneria americana* Michx. This site was revisited during the summer of 1998. The number of individual plants had declined to twelve. Signs of habitat degradation were apparent, resulting from landowner development of the shoreline. *Myriophyllum sibiricum*, *P. robbinsii*, and *R. aquatilis* var. *diffusus* also exhibited a substantial decrease in their population sizes. A search of the sheltered, undisturbed backwaters of Stone Lake revealed no additional plants of *B. beckii*.

Despite the unsuccessful attempt to locate additional beds of *Bidens beckii* in Stone Lake, an investigation during the summer of 2000 of the aquatic plant communities in Pine Lake, which is located directly north of and connected to Stone Lake, resulted in the discovery of another population of the water marigold. This population was larger than the one previously reported for Stone Lake, yet it too was threatened by shoreline development along the northwest shore of the highly populated island. Other species growing in association with *B. beckii* included *Ceratophyllum demersum* L., *Myriophyllum spicatum* L., *Najas flexilis* (Willd.) Rostk. & Schmidt, *Stuckenia pectinata* (L.) Börner, and *Zosterella dubia* (Jacq.) Small.

In June of 1998, a population of *Bidens beckii* (> 500 plants) was found at a second site in LaPorte County in a bay along the southwest shore of Hudson Lake. Plants were found growing in water up to 1.5 m in depth. This population was extensive, form-



ing large dense stands encompassing most of the area within the bay. Like the Stone Lake plants, these plants had neither produced emergent foliage nor flowered. Hudson Lake is a marl lake that is largely dominated by the growth of *Chara globularis* Thuill., which at the time formed large beds that covered much of the littoral zone. Other common submersed species found with *B. beckii* included *Elodea nuttallii* (Planch.) H. St. John, *Potamogeton crispus* L., *P. gramineus* L., *Utricularia purpurea* Walter, and *Zosterella dubia*.

In late August of 1998, the first flowering population of *Bidens beckii* was found in 0.5 m of water off the western shore of Wauhob Lake, Porter County. Yellow emergent flowers could be seen among the floating leaves of *Brasenia schreberi* J. F. Gmel. and *Nymphaea odorata* Aiton subsp. *tuberosa* Wiersema & Hellq. At the time, only seven plants had flowered, but others had floral buds. Although the number of plants present was quite low (< 30), the plants appeared to be secure and quite vigorous in this habitat. Discussions with the lakefront property owner on the status of the species resulted in an agreement by the owner not to rake “weeds” from the littoral zone in this area.

VOUCHER SPECIMENS: Indiana: LaPorte Co., LaPorte, Stone Lake, 41°36'43"N, 86°45'03"W, SW of navigable channel, 10 Jun 1998, Alix s.n. (BUT); Lake Park, Hudson Lake, 41°42'43"N, 86°33'00"W, in water 1.5 m deep off SW shore, 22 Jun 1998, Scribailo & Alix 138 (PUNC); LaPorte, Pine Lake, 41°37'40"N, 86°45'07"W, S shore of upper Pine Lake towards N shore of island and E of intersection of Holton Rd. and Island Dr., 7 Sep 2000, Alix s.n. (BUT); Porter Co., Valparaiso, Wauhob Lake, 41°32'01"N, 87°02'40"W, in water 0.75 m deep near boat rental dock, 21 Aug 1998, Scribailo 155, 156 (PUNC).

***Lemna valdiviana* Phil.** *Lemna valdiviana* (pale duckweed) is one of eight *Lemna* species known to occur in Indiana. Its common name is derived from the pale green appearance of its fronds. The intensity of green color is dependent upon growth conditions, the thickness of the frond, and the content of chlorophyll in the different cell layers (Landolt 1986). The fronds of *L. valdiviana* are often asymmetrical, giving them a distinctive falcate shape (Mohlenbrock 1970), resembling the sole of a shoe. Each frond has a single vein; a character shared with only one other North American *Lemna* species, *L. minuta* Kunth, which also occurs in Indiana. *Lemna valdiviana* can be distinguished



from *L. minuta* by the greater length of the vein, which in the former species distally exceeds the extension of air space tissue (Landolt 1986, 2000). Distinguishing between these two species can be very difficult and often requires the clearing and subsequent examination of fronds using light microscopy (Landolt 1986).

*Lemna valdiviana* was first recorded for Indiana as *L. cyclostata* (Elliot) Chev. by Deam (1932), who collected this species from Noble County. Hicks (1937) summarized Deam's locality data for this species in connection with the upcoming flora. In his *Flora of Indiana*, Deam (1940) reported *L. valdiviana* as being "local in the lake area." Deam referred to map 582 in the text of his flora regarding the distribution of *L. valdiviana*, however, the correct map citation is actually 578. Without the erratum pamphlet that was subsequently provided for the flora, or the correct distribution map in Hicks (1937) for comparison, it is not possible to determine whether the number cited in the text, the maps themselves, or the species designations are in error. Map 578 indicates *L. valdiviana* from Lagrange, Noble, and Wells Counties in the northeastern part of the state. An examination of herbarium specimens from Indiana University (IND) indicated that this species had been collected from Noble County in 1931 as discussed above (*Deam 50405*), and Lagrange County in 1933 (*Deam 54088*). Swink and Wilhelm (1994) did not report this species for the northwestern counties of Indiana. There is only one EOR for this species, which reports its occurrence from Beaver Dam Lake fen in Steuben County in 1974. This site was visited in 2000, but we were unsuccessful in locating a population of this species. *Lemna valdiviana* is listed as extirpated in 50% of the Great Lakes states (Table 1).

On September 22, 1997, the pale duckweed was found in the eastern backwaters of Long Lake, Porter County, Indiana. Plants of *Lemna valdiviana* were typically found in small tangled masses just below the water's surface. This habit is one quite often observed in the related species *L. trisulca* L. Colonies were rare to occasional and were restricted to the northeastern shoreline and a small backwater pond off of the lake, which largely consisted of patchy stands of *Cephalanthus occidentalis* L. Other associated plant species included *Ceratophyllum demersum*, *L. minor* L., *L. trisulca*, *Proserpinaca palustris* L., and *Utricularia vulgaris* L.

On October 4, 2001, an additional population of *Lemna val-*



*diviana* was discovered at the north end of Kaiser Lake beside the public boat launch in Kosciusko County in northeastern Indiana. Plants were abundant, either floating on or submersed just below the surface, and intermixed with *L. minor*, *L. trisulca*, *Spirodela polyrrhiza* (L.) Schleid., and *Wolffia columbiana* H. Karst. Clumps of this species were also found submersed and entangled with the leaves of *Ceratophyllum demersum* and *Myriophyllum spicatum*. Lemnid species covered over 50% of the lake's surface area and harbored an extensive population of *L. valdiviana*, comprising an estimated 30% of the mat.

VOUCHER SPECIMENS: Indiana: Porter Co., Valparaiso, Long Lake, 41°31'31"N, 87°02'49"W, in eastern backwaters of the lake, 22 Sep 1997, *Scribailo & Alix 131* (PUNC); Kosciusko Co., Yellowbanks, Kaiser Lake, 41°18'59"N, 85°39'42"W, large mat E of public access site, 4 Oct 2001, *Scribailo & Alix 506* (PUNC).

***Myriophyllum pinnatum* (Walter) Britton, Sterns & Poggenb.** *Myriophyllum pinnatum* is one of five perennial water-milfoil species occurring in Indiana. It is common throughout the Midwest, though endangered in Indiana (Table 1). This species is quite variable in its morphology and habitat, producing whorled pinnatifid leaves on elongated stems when submersed, and branching more freely with scattered leaves when it is anchored along the shoreline (Correll and Correll 1975). *Myriophyllum pinnatum* is more easily recognized as a terrestrial species (Aiken 1981) and can be confused with *M. heterophyllum* Michx., another native species in Indiana that will often produce a short terrestrial form on exposed mudflats as summer lake levels decline. When available, mature fruits provide the best characters for distinguishing between the two species. Although the fruits of both species are 4-angled and have dorsal ridges, these ridges are smooth in *M. heterophyllum*, but are tuberculate in *M. pinnatum*.

Historical records indicate *Myriophyllum pinnatum* was collected by Deam (1940; as *M. scabratum* Michx.) from Jasper County, Indiana, approximately 0.8 km west of the Teft Bridge in the Kankakee River. Swink and Wilhelm (1994) reported the Deam specimen in *Plants of the Chicago Region*, but did not report any new locations for this species in the northwestern counties of Indiana. An EOR reveals that *M. pinnatum* was collected from Fishtrap Lake, LaPorte County, in July of 1985 by



J. Aldrich and J. Wilhelm (the latter possibly Gerould Wilhelm), who stated that this species was abundant at the time of collection and was found intermixed with plants of *M. heterophyllum*. A comprehensive inventory of Fishtrap Lake in 1998 by the current authors did not result in the discovery of this species, but only verified the presence of *M. heterophyllum*. Because *M. pinnatum* and terrestrial variants of *M. heterophyllum* can be morphologically similar with pinnate leaves, it is our opinion that the report from Aldrich and Wilhelm may be erroneous. No herbarium specimens could be located to evaluate the record from Aldrich and Wilhelm.

In 1997, a small population of *Myriophyllum pinnatum* (20 plants) was found along the northern shore of a small cove of Loomis Lake, Porter County, Indiana, which is the first county directly north from where Deam (1940) collected his specimen. Plants of *M. pinnatum* were found on the muddy shoreline in shallow water (0.20 m). Associated species included *Ceratophyllum demersum*, *Elodea nuttallii*, *Lemna minuta*, *L. trisulca*, *Polygonum amphibium* L., *Spirodela polyrrhiza*, *Wolffia borealis* (Engelm.) Landolt, *W. brasiliensis* Wedd., and *W. columbiana*. Although most plants found at this site were terrestrial, some were submersed with emergent flowering and fruiting spikes. The fruits were diagnostic in identification and had very distinct tuberculate dorsal ridges, a purple tinge, and were subtended by coarsely toothed bracts (Aiken 1981).

Two additional populations of *Myriophyllum pinnatum* were subsequently discovered in adjoining counties. The first population was found in 1998 at Chamberlain Lake, St. Joseph County, where both flowering and fruiting plants were present. Like the aforementioned population, plants were found either growing as terrestrial variants exposed on mud flats or in their submerged form in shallow water along the sheltered northwest shore. The most common species associates were *Ceratophyllum demersum* and *Nuphar advena* (Aiton) W. T. Aiton, the latter extending over half the distance across the lake. The second population was discovered in the fall of 2000 on the southern shoreline of Stone Lake, LaPorte County. The population at this site was primarily terrestrial and strictly vegetative, sprawling across the muddy shoreline for nearly 3 m. Species associated with *M. pinnatum* at this site included *Pontederia cordata* L. and *Sagittaria latifolia* Willd.



VOUCHER SPECIMENS: Indiana: Porter Co., Valparaiso, Loomis Lake, 41°31'04"N, 87°03'28"W, northern shore of small cove, 8 Aug 1997, *Alix* 67 (PUNC); St. Joseph Co., West Field, Chamberlain Lake, 41°39'22"N, 86°22'00"W, in shallow water along north shore, 7 Sep 1998, *Scribailo* 184 (PUNC); LaPorte Co., LaPorte, Stone Lake, 41°36'34"N, 86°44'39"W, on shore across from intersection of Lakeshore Dr. and Craven Dr., 15 Sep 2000, *Alix* 341 (PUNC).

*Najas gracillima* (A. Braun ex Engelm.) Magnus. *Najas gracillima* (thread-like naiad) is morphologically similar to *N. flexilis* and *N. minor* All., which also occur in Indiana. These species are easily confused because of the presence of extensive plasticity in vegetative characters. The most definitive characters for positive identification of naiad species are seed shape and seed coat reticulation patterns, which can only be determined microscopically. Fruits of *N. gracillima* have an off-center style at their apex, and the seed coats have areoles that are much longer than broad (Haynes 1979, 2000).

*Najas gracillima* is a relict coastal plain aquatic plant species in the Great Lakes region (Peattie 1922; Reznicek 1994) and is particularly common in the New England states (Haynes 2000; Stuckey 1983). Stuckey (1983) has commented on the rarity of this species in Ohio, Illinois, and Indiana and has cited macrofossil records (Watts 1970; Wright and Watts 1969) as indicating that the species was once far more common in this region. Stuckey postulated that the xerothermic period (beginning 8000 YBP) that advanced a "Prairie Peninsula" (Gleason 1923; Transeau 1935) eastward for a period of some 3000 years would have resulted in the loss of extensive wetland and aquatic habitat that could have contributed to the loss of populations of this species. Recent evidence however, questions the true extent of the "Prairie Peninsula" xerothermic in the Midwest (Baker et al. 1996). More paleobotanical studies utilizing aquatic plant macrofossils are needed to further determine the impact of the postulated xerothermic period on aquatic plant distributions, particularly in the eastern states of the Midwest.

It is our contention that the apparent scarcity of *Najas gracillima* in the Great Lakes region, and particularly in Indiana where it is endangered (Table 1), may actually be an artifact of undercollecting. *Najas flexilis* is very common in Indiana and is often found growing in abundance with occasional plants of *N. gracillima*, so that the latter may easily be overlooked.



We are aware of a single EOR from Pulaski County in north-west Indiana collected by Kriebel in 1938, although it has been collected from two southern counties within the state. Deam (1940) reported the 1935 specimen collected in Lawrence County (*Kriebel 3477*, IND). Wentz and Stuckey (1971) reported the species from Knob Lake, Jackson County (7 Sep 1958, *Starcs 2123*, BUT; 19 Jul 1970, *Starcs 3100*, BUT).

We first identified this slender and delicate species from the shallow waters of the eutrophic Mink Lake in Porter County. Eighty percent of the water's surface area was choked by *Nuphar advena* and the mean water depth within the littoral zone was less than 1.0 m. Plants of *Najas gracillima* were common, growing along the northeastern and northwestern shorelines at a depth of 0.5 m. Plants had a definite red tinge to their leaves and stems. We have observed distinctive red and green color morph variation in this species at many localities, but do not know the cause of this variation. This red coloration was also observed in plants of *Elodea nuttallii*. Other associated species included *Ceratophyllum demersum*, *C. echinatum* A. Gray, *Lemna trisulca*, *Najas flexilis*, *Nuphar advena*, *Nymphaea odorata* subsp. *tuberosa*, *Potamogeton amplifolius* Tuck., *P. crispus*, *P. pusillus* L. subsp. *tenuissimus* (Mert. & W. D. J. Koch) R. R. Haynes & Hellq., *Utricularia gibba* L., and *U. vulgaris*.

Although it has been suggested that *Najas gracillima* may not have the ability to withstand eutrophic waters (Haynes 1979; Wentz and Stuckey 1971) this does not appear to be the case at the Mink Lake site. The population at Mink Lake could be near its tolerance limits to eutrophication and may decline or disappear with time. Fertilizer runoff from an adjacent golf course is the primary source of nutrients contributing to the eutrophication.

In the latter part of August of 1998, *Najas gracillima* was found in Silver Lake, LaPorte County. This population was quite extensive, forming dense patches from the eastern to the southern shoreline. The plants had a lime-green coloration and many had set fruit. Plants growing in association with *N. gracillima* were *N. flexilis*, *Nuphar advena*, *Nymphaea odorata* subsp. *tuberosa*, *Potamogeton amplifolius*, *P. diversifolius* Raf., *P. epihydrus* Raf., *P. pusillus* subsp. *tenuissimus*, and *Zosterella dubia*.

VOUCHER SPECIMENS: Indiana: Porter Co., Valparaiso, Mink Lake, 41°31'49"N, 87°02'14"W, in water 0.5 m deep off the northeastern shoreline,



10 Jun 1997, *Scribailo & Alix 60* (PUNC); LaPorte Co., Rolling Prairie, Silver Lake, 41°41'25"N, 86°35'45"W, in shallow water along the southwestern shoreline, 29 Aug 1998, *Scribailo & Alix 179* (PUNC); 7 Aug 2000, *Alix s.n.* (BUT).

***Potamogeton bicupulatus* Fernald.** *Potamogeton bicupulatus* (snail-seed pondweed) is one of the most diminutive and delicate pondweeds of North America. Like *Najas gracillima*, this species is another of several coastal plain submersed aquatic plant species represented in the northern Great Lakes region (Peattie 1922; Reznicek 1994). It is one of only three linear-leaved pondweed species in North America having dimorphic inflorescences and embryos with more than one complete spiral; it is restricted to acidic waters (Haynes and Hellquist 2000). *Potamogeton bicupulatus* is morphologically similar to *P. diversifolius*, which occurs in many of the southern and central counties of Indiana, as well as a few localities in northwestern Indiana. Peattie (1922, 1930) actually noted *P. hybridus* (referenced in brackets in his works as *P. diversifolius*) as being found in the intradunal pond region of Indiana. These specimens, which were collected from Dune Park in Porter County (4 Jul 1906, *Hill 132*, F; 18 Sep 1903, *Hill 156*, F), were subsequently annotated as *P. bicupulatus* by both Barre Hellquist and Robert Haynes and are the only known historical records for the species in the state. We are unaware of any EORs for this species.

In midsummer of 1998, four plants of *Potamogeton bicupulatus* were located in a shallow drainage ditch, which flowed into Chamberlain Lake, St. Joseph County. The culvert appeared to have been recently installed and sand within the ditch was part of a pile on top of the pipe. It is quite possible that the sand may have been brought in from another area that contained a small seed bank of this pondweed. Only one of four plants had set seed and seed set for that individual was estimated at 50%. A survey of Chamberlain Lake yielded no other plants of *P. bicupulatus*. Associated species included *Ceratophyllum demersum*, *Nuphar advena*, and *Sagittaria latifolia*.

VOUCHER SPECIMEN: Indiana: St. Joseph Co., West Field, Chamberlain Lake, 41°39'21"N, 86°21'57"W, near drainage ditch, 7 Jul 1998, *Alix 143* (PUNC).

***Potamogeton epihydrus* Raf.** *Potamogeton epihydrus* (ribbon-leaved pondweed) is one of the most distinctive and easily



recognized North American species of pondweed. Its thin, translucent, strap-like submersed leaves and elliptic floating leaves readily identify this species. Unlike many pondweeds, there are no intergradations between leaf types present. The only North American species morphologically similar to *P. epihydrus* is *P. tennesseensis* Fernald, which is distinguished by having long-tapering apices in the submersed leaves (Haynes and Hellquist 2000), however the latter species is not found in Indiana.

*Potamogeton epihydrus* is rare in the lower midwestern states and common in Michigan, Wisconsin, and the eastern states (Stuckey 1983). It is very rare in Indiana where it is listed as endangered (Table 1). This species has previously been collected from only one location (Deam 1940; Tryon 1937; Swink and Wilhelm 1994), at State Line Creek in LaPorte County (8 Aug 1936, *Tryon* 30593, BUT; 014212, ND). Although a review of EORs indicates that this species has been recorded from Ridinger Lake in Kosciusko County and Loon Lake in Steuben County, no herbarium specimens are available to corroborate these reports. In addition, repeated visits by the authors to both of the aforementioned lakes yielded no populations of *P. epihydrus*. Extensive populations of *P. natans* L. were present at both lakes. Observed plants had both smaller floating leaves and longer stipules than are typically representative of this species in Indiana. The combination of these two characters at the two locations might have resulted in the erroneous reporting of the latter species as *P. epihydrus*. It is noteworthy that these lakes are marl lakes, typically of higher pH and alkalinity, and would not likely support the growth of a softer water species like *P. epihydrus*.

In 1997, *Potamogeton epihydrus* was discovered at Silver Lake in LaPorte County where it grew along the shallow sandy banks of the eastern and southeastern shores. In Silver Lake, the ribbon-leaved pondweed formed small patchy beds in water from 15 to 50 cm deep. Seed set was close to 100% ( $n = 40$ ) on plants from this population. Associated species included *Najas gracillima* and *P. diversifolius*.

In the summer of 1999, *Potamogeton epihydrus* was found at two additional locations in LaPorte County approximately 1.5 km west of Silver Lake in two small ponds behind the Rolling Prairie Elementary School. The species was also discovered at Clear Lake in Porter County. Plants at Clear Lake were found at greater water depths (1.25 m) than at the LaPorte locations. Seed set of



plants at this location was approximately 50% ( $n = 20$ ). Waters of the LaPorte County lakes were more turbid than those of Clear Lake, which may have inhibited the establishment of the ribbon-leaved pondweed at greater depths.

According to Hellquist (1980), Nichols (1999), and Stuckey (1983) *Potamogeton epihydrus* is a species of circumneutral to soft water lakes and ponds. Habitats of this type are limited in Indiana, where calcareous groundwaters and marl deposits have produced a majority of lakes of alkaline pH. Stuckey (1983) recognized *P. epihydrus* as an additional example of an aquatic plant that may have once been more extensive in range prior to the postulated xerothermic period.

VOUCHER SPECIMENS: Indiana: LaPorte Co., Rolling Prairie, Silver Lake, 41°41'27"N, 86°35'33"W, in shallow water of southeastern littoral zone, 23 Sep 1997, *Scribailo & Alix 132, 133* (PUNC); 7 Aug 2000, *Alix s.n.* (BUT); Prairie Pond, 41°40'57"N, 86°36'34"W, in shallow water off S shore directly in front of observation deck, 7 Aug 1999, *Alix 255* (PUNC); Porter Co., Jackson Township, Clear Lake, 41°33'11"N, 86°55'55"W, in shallow water of small bay near W side of lake, 21 Jun 1999, *Scribailo & Alix 203* (PUNC).

***Potamogeton pulcher* Tuck.** *Potamogeton pulcher* (spotted pondweed) is a coastal plain species with a predominantly southeastern range (Haynes and Hellquist 2000), and is not only endangered in Indiana, but is also one of the rarest pondweeds found in the Great Lakes region (Table 1). The localities of this species in Indiana are few and include: Jasper County (Welch 1931); Sullivan County (Deam 1940); Pine Station in Lake County (Hill 1885); Miller Woods Pond in Lake County in 1982 (*Simonin 26*, MOR); intradunal swales west of Miller in Lake County in 1985 (*Wilhelm 12955*, MOR) and 1991 (*Wilhelm & Wetstein 19722*, MOR); and Little Lake in Porter County in 1991 (*Plampin & Newgent 1-1991*, MOR). In July of 1997, we revisited the Little Lake site in the Indiana Dunes National Lakeshore and found only a single plant of *P. pulcher* growing within a monospecific stand of cattails.

In September of 1997, a small population ( $< 10$  plants) of *Potamogeton pulcher* was found off the eastern shore of Fishtrap Lake in LaPorte County. The black-spotted stems and petioles along with the cordate-based floating leaves were quite prominent in these plants and are distinctive features of this pondweed species. The submersed leaves were lanceolate, up to 9.0 cm in



length and averaging 1.2 cm wide, having wavy margins and tapering at the base to petioles 1.0 cm long (e.g., Beal 1977). No flowering or fruiting was observed in these plants.

The population of spotted pondweed was 3 m from the eastern shoreline, growing in water 0.75 m in depth. Associated species included *Nuphar advena*, *Potamogeton robbinsii*, and *Utricularia vulgaris*. This site was revisited in July of 1998, but no plants of *P. pulcher* were found.

In September of 1999, an extensive population of *Potamogeton pulcher* was found in sloughs along the north and south sides of County Road 700 North within the Jasper-Pulaski Fish and Wildlife Area in Jasper County. Although the population consisted of hundreds of plants, none had flowered. Associated species included *Elodea nuttallii*, *Myriophyllum heterophyllum*, and *Nymphaea odorata* subsp. *tuberosa*.

In the summer of 2000, two additional populations of this species were found. The first population was located in shallow former sand-mining ponds located in the dune and swale topography of Lake County in an area known as the Bonji Tract. This population consisted of approximately 30 plants growing in association with *Proserpinaca palustris* in water only 0.25 m deep at the base of a small stand of *Scirpus pungens* Vahl. The second population was found within a remnant area of the Great Marsh in the Nature Preserve portion of the Indiana Dunes State Park in Porter County. This population consisted of less than 10 plants growing with *Ceratophyllum demersum*, *Nuphar advena*, *Peltandra virginica* (L.) Schott, and *Sparganium americanum* Nutt.

The multiple leaf types observed in *Potamogeton pulcher* largely agree with the descriptions by Robbins (1867), who identified the presence of three kinds of leaves in this species: floating leaves roundish-ovate, cordate, or ovate-oblong, all alternate; upper submersed leaves usually lanceolate, acute at base and with very long acuminate tips, very thin, undulate, short-petioled; lowest submersed leaves thicker, flat, oval or oblong with a rounded base, or spatulate-oblong, on longer petioles. Although we completely agree with these descriptions for floating and upper submersed leaves, we found the lowermost submersed leaves to be either lanceolate or spatulate, but not ovate. In addition, the lowermost submersed leaves of plants at the Jasper-Pulaski Fish and Wildlife Area had distinctive dentate margins with less than ten



teeth per side. This observation has not been previously reported for this species.

VOUCHER SPECIMENS: Indiana: Jasper Co., Jasper-Pulaski Fish and Wildlife Area, 41°09'30"N, 86°56'24"W, in road ditch next to gravel pit fishing area, 7 Sep 1999, *Scribailo & Alix* 301, 302, 303 (PUNC); 21 Jul 2000, *Alix* s.n. (BUT); Lake Co., Gary, Bonji Tract, 41°37'12"N, 87°23'38"W, in shallow water directly east of Clark and Pine Nature Preserve ca. 100 m after crossing Clark St., 5 Aug 2000, *Scribailo & Alix* 315 (PUNC); LaPorte Co., LaPorte, Fishtrap Lake, 41°38'03"N, 86°43'44"W, near E shore, 29 Sep 1997, *Alix* 134 (PUNC); Porter Co., Indiana Dunes National Lakeshore, Great Marsh in Dunes State Park, 41°39'29"N, 87°02'49"W, in shallow water next to bridge/observation platform on trail #2, 5 Aug 2000, *Scribailo & Alix* 328 (PUNC).

***Potamogeton vaseyi* J. W. Robbins.** *Potamogeton vaseyi* appears to be a species of softer waters (Hellquist 1980; Hellquist and Crow 1980; Hopkins 1919; Nichols 1999). The scarcity of softer water lakes in Indiana is likely a factor contributing to the rarity of this species in the state. This species is state-listed in six of the eight states in the Great Lakes region (Table 1).

Small populations of *Potamogeton vaseyi* (< 50 plants) were discovered at Round and Wauhob Lakes, Porter County, in the middle of June 1997. *Potamogeton vaseyi* was common off the northwest shore of Wauhob Lake and rare in Round Lake. Associated species included *Ceratophyllum demersum*, *Myriophyllum heterophyllum*, *M. verticillatum* L., *Potamogeton amplifolius*, *P. richardsonii* (A. Benn.) Rydb., *Utricularia gibba*, *U. purpurea*, and *U. vulgaris*.

During the summer of 1997, two additional populations of *Potamogeton vaseyi* were discovered in LaPorte County. The first population was found along the eastern shoreline of Fishtrap Lake, LaPorte County, and was comprised of four beds, having a total coverage area of over 120 m<sup>2</sup>. Unlike the plants of Round and Wauhob Lakes, these plants were robust and many were either in flower or had fruited profusely. Seed had set on emergent spikes of individuals closer to shore before the inflorescences on deeper plants had emerged from the water. Individual plants from Fishtrap Lake produced multiple infructescences, whereas individuals from Round and Wauhob Lakes each produced only a single infructescence. Associated species included *P. pulcher*, *P. pusillus* subsp. *tenuissimus*, and *P. robbinsii*.

The second population from LaPorte County was discovered



in Saugany Lake (Alix and Scribailo 1998), approximately 16 km northeast of the Fishtrap population. Plants were few in number ( $< 25$ ) and were found in a small bay of the lake near the west beach. A majority of these plants were growing in relatively shallow water no deeper than 1.5 m. Although plants at this site were in flower and had produced turions, no seeds were observed. Associated species included *Myriophyllum spicatum*, *Potamogeton amplifolius*, *P. foliosus* Raf. subsp. *foliosus*, *P. praelongus* Wulfen, *Ranunculus aquatilis* var. *diffusus*, *Utricularia vulgaris*, and *Zosterella dubia*.

VOUCHER SPECIMENS: Indiana: LaPorte Co., LaPorte, Fishtrap Lake, 41°38'04"N, 86°43'48"W, eastern shoreline directly NE of VFW dock, 22 Jun 1997, *Alix s.n.* (BUT); Birchim, Saugany Lake, 41°43'13"N, 86°35'13"W, in shallow water next to W beach area, 13 Aug 1997, *Alix s.n.* (BUT); Porter Co., Valparaiso, Wauhob Lake, 41°32'00"N, 87°02'40"W, off W shore near boat rental dock in water 0.75 m deep, 15 Jun 1997, *Alix s.n.* (BUT); Round Lake, 41°31'57"N, 87°02'27"W, collected from mouth of channel, 15 Jun 1997, *Scribailo 66* (PUNC).

#### CONSERVATION ISSUES

There are many concerns regarding the conservation of rare aquatic plant species in the state of Indiana. As previously noted, lakes of the state are typically small and shallow, making them more susceptible to anthropogenic impacts. Although efforts have been made to improve land use by adopting better management practices such as no-till farming, many lakes continue to suffer from an accelerated rate of eutrophication due to nutrient loading from agricultural runoff.

Many of Indiana's lakes have extensively developed shorelines consisting of cottages with concrete retaining walls and mowed lawns to the water's edge. Buffer strips, which would protect shorelines, provide habitat, and intercept land runoff, are underutilized in the state. Because of the importance of farming in Indiana, many farmers view ditches and creeks primarily as drainage and irrigation sources without concern for the possible impact of these practices on the waterways involved.

A major problem in assessing the status of rare aquatic plant species in Indiana is the almost complete lack of baseline historical surveys on which to base evaluations of rarity. As a result, it is difficult to ascertain whether species are rare because of



habitat destruction, because lake quality has been degraded, or because they have always been rare. Issues of rarity are of particular concern with the coastal plain species discussed here. Populations of these species in the Great Lakes region are widely disjointed from their predominantly eastern ranges and may represent unique genotypes of importance to conservation (Reznicek 1994).

Most assessments of aquatic plant communities in Indiana are carried out through the Lake and River Enhancement (LARE) Program of the Indiana Department of Natural Resources (IDNR), which awards lake diagnostic grants to private consulting firms. Aquatic plant inventories are required as part of these surveys. The consulting firms involved often do not have the personnel or time to comprehensively survey and identify each species. As a result, these surveys are of limited value because they are often based on one day of collecting, during which only the most common species are identified. In addition, voucher specimens are rarely prepared or deposited for proper documentation. Condoning the preparation of voucher specimens of course assumes that the collector would assess the abundance of rare species prior to collection and possibly provide GPS coordinates as an alternative for species that are exceptionally rare.

Personnel from the IDNR are often asked to make decisions on lake projects involving such diverse issues as shoreline development, herbicide application, and dredging that may be based on the aforementioned data. An additional problem is that IDNR biologists do not typically have the necessary training or time to identify populations of rare species that might be impacted. Where herbicide application permits are required and evaluated by IDNR for public lakes, it is often the herbicide applicator that has conducted the aquatic plant inventory, raising the question of vested interest.

Herbicide treatment of aquatic plants in Indiana is a multimillion-dollar industry and is by far the most prevalent form of aquatic plant control utilized in Indiana. Unfortunately, there are no state permit requirements for application of herbicides in private lakes. Approximately 50% of Indiana Lakes are considered public because there is public access of some kind. It is important to note though, that since the larger lakes tend to be those that have public access, approximately 80% of the total acreage of Indiana lakes could probably be deemed as public (Carol New-



house, Indiana Department of Environmental Management, pers. comm.).

As of July 1, 2002, changes to Indiana state law will reduce the extent to which a riparian resident can treat aquatic vegetation in a public lake without a permit. Formerly, it was not to exceed 50% of the aquatic vegetation area or one-half acre, whichever was less. The new ruling specifies not to exceed 25 ft. along the legally established, average, or normal shoreline and out to a water depth of 6 ft., which now limits the area of treatment to 625 ft<sup>2</sup>. It is important to note that the old ruling only applied to chemical treatment, whereas the new ruling governs any type of control method. Although this change represents a positive step favoring conservation of aquatic plants, the regulation still allows multiple residents along a shoreline to eradicate major portions of the aquatic vegetation without the need of a permit. Even if permits are not required for small-scale herbicide treatment in lakes, prior notification of local DNR biologists should be required of all proposed applications, so they can assess if there might be negative impacts on rare aquatic plant species.

A major issue concerning the success of aquatic plant conservation in Indiana is the apparent lack of understanding by the public of the role of aquatic plants in lake ecosystem dynamics. People in Indiana, as in other states, typically want beaches that look like swimming pools. Few lake residents seem to make the connection between aquatic plants and the health of fish populations. This lack of understanding leads to the misconception that the aquatic plant beds can be eradicated without any effect on desirable game fish or other aspects of lake health. Lakeside residents are also seemingly unaware of the importance of aquatic plant beds in reducing shoreline erosion and trapping sediments and nutrients. Education programs are needed to enhance public awareness of the importance of aquatic plants in the maintenance of lake quality. Fortunately, Indiana recognizes many of these issues as problems, and has a variety of education and volunteer programs designed to enhance the understanding of lake residents. The state is also currently drafting more rigorous requirements for the sampling of aquatic plants during lake quality surveys.

ACKNOWLEDGEMENTS. The authors thank two anonymous reviewers for comments on the manuscript. The authors wish to



thank the curators and staff members at BUT, F, IND, MOR, and ND for their assistance in transcribing herbarium specimen label data. In addition we are grateful for access privileges to Silver Lake granted to us by Amy Huber of the Silver Lake Conservation Committee. We greatly appreciate the comments and suggestions made by Dr. C. Barre Hellquist on an earlier version of this paper. Fieldwork for this study was supported by grants from the Indiana Department of Natural Resources, Division of Nature Preserves.

## LITERATURE CITED

- AIKEN, S. G. 1981. A conspectus of *Myriophyllum* (Haloragaceae) in North America. *Brittonia* 33: 57–69.
- ALIX, M. S. AND R. W. SCRIBAILO. 1998. Aquatic plant species diversity and floristic quality assessment of Saugany Lake, Indiana. *Proc. Indiana Acad. Sci.* 107: 123–139.
- BAKER, R. G., E. A. BETTIS, D. P. SCHWERT, D. G. HORTON, C. A. CHUMBLEY, L. A. GONZALEZ, AND M. K. REAGAN. 1996. Holocene paleoenvironments of northeast Iowa. *Ecol. Monogr.* 66: 203–234.
- BEAL, E. O. 1977. A manual of marsh and aquatic vascular plants of North Carolina with habitat data. Tech. Bull. No. 247, North Carolina Agric. Exp. Sta., Raleigh, NC.
- CARPENTER, S. R. AND D. M. LODGE. 1986. Effects of submersed macrophytes on ecosystem processes. *Aquatic Bot.* 26: 341–370.
- CORRELL, D. S. AND H. B. CORRELL. 1975. Aquatic and Wetland Plants of Southwestern United States, Vol. 2. Stanford Univ. Press, Stanford, CA.
- COULTER, S. 1900. A catalogue of the flowering plants and of the ferns and their allies indigenous to Indiana. Rep. (Annual) Indiana Geol. Survey 1899: 553–1074.
- DEAM, D. C. 1932. Plants new or rare to Indiana, XVIII. *Proc. Indiana Acad. Sci.* 42: 47–49.
- . 1940. Flora of Indiana. Indiana Dept. Conservation, Indianapolis, IN.
- FLORA OF NORTH AMERICA EDITORIAL COMMITTEE, EDS. 1993+. Flora of North America North of Mexico. 4+ vols. Oxford Univ. Press, Oxford and New York.
- FREY, D. G. 1966. Limnology, pp. 297–320. *In*: A. A. Lindsey, ed., Natural Features of Indiana. Indiana Acad. Sci., Indianapolis, IN.
- GLEASON, H. A. 1923. The vegetational history of the Middle West. *Ann. Assoc. Amer. Geogr.* 12: 39–85.
- AND A. CRONQUIST. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada, 2nd ed. The New York Botanical Garden, Bronx, NY.
- HAYNES, R. R. 1979. Revision of North and Central American *Najas* (Najadaceae). *Sida* 8: 34–56.
- . 2000. Najadaceae, pp. 77–83. *In*: Flora of North America Editorial Committee, eds., Flora of North America North of Mexico, Vol. 22: Magnoliophyta. Oxford Univ. Press, Oxford and New York.



- AND C. B. HELLQUIST. 2000. Potamogetonaceae, pp. 7–25. *In*: Flora of North America Editorial Committee, eds., Flora of North America North of Mexico, Vol. 22: Magnoliophyta. Oxford Univ. Press, Oxford and New York.
- HELLQUIST, C. B. 1980. Correlations of alkalinity and the distribution of *Potamogeton* in New England. *Rhodora* 82: 330–345.
- AND G. E. CROW. 1980. Aquatic vascular plants of New England, Part 1. Zosteraceae, Potamogetonaceae, Zannicheliaceae, Najadaceae. Bull. No. 515, New Hampshire Agric. Exp. Sta., Durham, NH.
- HICKS, L. E. 1937. The Lemnaceae of Indiana. *Amer. Midl. Naturalist* 18: 774–789.
- HILL, E. J. 1885. Some Indiana plants. *Bot. Gaz.* 10: 262–263.
- HOPKINS, L. S. 1919. The occurrence and distribution of Vasey's pondweed in northeastern Ohio. *Torreyia* 19: 243–244.
- ILLINOIS ENDANGERED SPECIES PROTECTION BOARD. 1999. Checklist of endangered and threatened animals and plants of Illinois. Illinois Dept. Natural Resources, Springfield, IL.
- INDIANA NATURAL HERITAGE DATABASE. 1996. Endangered, threatened, and rare vascular plant species documented from Indiana. Indiana Dept. Natural Resources, Div. Nature Preserves, Indianapolis, Indiana. Web Site: <http://www.state.in.us/dnr/naturepr/endanger/plant.htm>.
- JEPPESEN, E., T. L. LAURIDSEN, T. KAIRESALO, AND M. R. PERROW. 1998. Impact of macrophytes on fish-zooplankton interactions in lakes, pp. 91–114. *In*: E. Jeppesen, M. Søndergaard, M. Søndergaard, and K. Christoffersen, eds., The Structuring Role of Macrophytes in Lakes. Ecological Studies, Vol. 131. Springer-Verlag, Inc., New York.
- LANDOLT, E. 1986. The family of Lemnaceae—A monographic study. 1. Veröffentlichungen der Geobotanischen Institutes der ETH, Stiftung Rübel, Zürich 71, Switzerland.
- . 2000. Lemnaceae, pp. 143–153. *In*: Flora of North America Editorial Committee, eds., Flora of North America North of Mexico, Vol. 22: Magnoliophyta. Oxford Univ. Press, Oxford and New York.
- MICHIGAN NATURAL FEATURES INVENTORY. 1999. Michigan's special plants list. Michigan Natural Features Inventory, Lansing, MI.
- MINNESOTA NATURAL HERITAGE DATABASE. 2000. Minnesota's list of endangered, threatened, and special concern species. Minnesota Dept. Natural Resources, Sect. Ecological Services, St. Paul, MN. Web Site: [http://www.dnr.state.mn.us/ecological\\_services/nhnrp/endlist.pdf](http://www.dnr.state.mn.us/ecological_services/nhnrp/endlist.pdf).
- MOHLENBROCK, R. H. 1970. The Illustrated Flora of Illinois: Flowering Plants, Flowering Rush to Rushes. Southern Illinois Univ. Press, Carbondale, IL.
- NATIONAL RESEARCH COUNCIL. 1992. Restoration of Aquatic Ecosystems: Science, Technology and Public Policy. National Acad. Press, Washington, DC.
- NICHOLS, S. A. 1999. Distribution and habitat descriptions of Wisconsin lake plants. Bull. 96, Wisconsin Geol. and Natural History Survey, Madison, WI.
- OHIO DIVISION OF NATURAL AREAS AND PRESERVES. 1998. Rare native Ohio plants: 1998–1999 status list. Ohio Dept. Natural Resources, Columbus, OH.
- PEATTIE, D. C. 1922. The Atlantic coastal plain element in the flora of the Great Lakes. *Rhodora* 24: 57–58.



- . 1930. Flora of the Indiana Dunes. Field Museum of Natural History, Chicago, IL.
- PENNSYLVANIA NATURAL DIVERSITY INVENTORY. 2002. Plants of special concern in Pennsylvania (Bocip) list. Pennsylvania Dept. Conservation and Natural Resources, Wild Plant Managemt. Progr., Harrisburg, PA.
- PEPOON, H. S. 1927. Flora of the Chicago Region. Bull. VIII, Natural History Survey, Chicago Acad. Sci., Chicago, IL.
- REZNICEK, A. A. 1994. The disjunct coastal plain flora in the Great Lakes region. Biol. Conservation 68: 203–215.
- ROBBINS, J. W. 1867. *Potamogeton*, pp. 484–490. In: A. Gray, Manual of the Botany of the Northern United States, 5th ed. Ivison, Blakeman and Co., New York.
- ROBERTS, M. L. 1985. The cytology, biology and systematics of *Megalodonta beckii* (Compositae). Aquatic Bot. 21: 99–110.
- STUCKEY, R. L. 1983. Absence of certain aquatic vascular plants from the Prairie Peninsula, pp. 97–104. In: R. Brewer, ed., Proc. 8th North American Prairie Conference, Western Michigan Univ., Kalamazoo, MI.
- SWINK, F. AND G. WILHELM. 1994. Plants of the Chicago Region, 4th ed. Indiana Acad. Sci., Indianapolis, IN.
- TRANSEAU, E. N. 1935. The Prairie Peninsula. Ecology 16: 423–437.
- TRYON, R. M., JR. 1937. Recent additions to the flora of Indiana. Proc. Indiana Acad. Sci. 47: 76–77.
- VOSS, E. G. 1996. Michigan Flora, Part III. Dicots (Pyrolaceae–Compositae). Cranbrook Inst. Sci. Bull. 61, Univ. Michigan Herbarium, Ann Arbor, MI.
- WATTS, W. A. 1970. The full-glacial vegetation of Northwestern Georgia. Ecology 51: 17–33.
- WELCH, W. 1931. Additions to the vascular flora of Jasper County, Indiana, I. Proc. Indiana Acad. Sci. 40: 119–121.
- WENTZ, W. A. AND R. L. STUCKEY. 1971. The changing distribution of the genus *Najas* (Najadaceae) in Ohio. Ohio J. Sci. 71: 321–342.
- WISCONSIN NATURAL HERITAGE PROGRAM. 1998. Wisconsin rare vascular plant working list. Bureau Endangered Resources, Wisconsin Dept. Natural Resources, Madison, WI.
- WRIGHT, H. E. AND W. A. WATTS. 1969. Glacial and vegetational history of northeastern Minnesota. Special Publ. Ser. SP-11, Minnesota Geol. Survey, Minneapolis, MN.
- YOUNG, S. M. 2001. New York natural program rare plant status list. April 2001. New York Natural Heritage Program, Albany, NY.